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Electricity Distribution Utilities and the Future: More than Just Wires

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1. Introduction¹

This chapter reviews the main challenges facing electricity distribution network utilities along technological, economic, and social dimensions. It also discusses the implications of challenges ahead for network utilities and provides some insights into the likely features of their future business models.

Electricity networks are a crucial part of the power system as they transport electricity from generators to end-users. The power grid consists of transmission and distribution networks that differ in voltage level, size, operation, and objectives. The transmission grid comprises high-voltage circuits designed to transfer bulk power from power plants to load centers, using step-up transformers to raise the voltage to the required level. Distribution networks deliver electric energy to end-users after receiving bulk power from the transmission grid. Circuits with different voltage levels in transmission and distribution networks are connected by substations.² Electricity is delivered through underground cables or overhead lines. Underground cables are often used in urban areas, whereas overhead lines are used for less densely populated and rural areas.

In a liberalized and unbundled model of the electricity sector, distribution networks are owned and operated by distribution network operators (DNOs). Each DNO serves a specific service area but has no direct financial relationship with final consumers (that is, DNOs do not sell electricity). End-users buy electricity from or sell to, retail suppliers. In many countries, prior to the liberalization of the sector in the 1990s, distribution networks were part of vertically integrated monopoly structures that owned and operated the four basic functions of the electricity system: generation, transmission, distribution, and retail supply. Liberalizing reforms led to the introduction of wholesale and retail markets for electricity. However, competition is not feasible in the electricity networks, and consequently, network companies are subject to economic regulation.

In the coming years, distribution networks will likely experience wide-ranging changes in their operating environments. Networks that were originally designed as passive transporters of electric energy face a shift in their operational paradigm in terms of bi-directional power flows and their use of information and communication technologies. Moreover, penetration of distributed generation sources, electric vehicles (EV), and storage facilities create techno-economic challenges that require grid upgrade, reinforcement, technological improvement, and, ultimately, the development of new business models (see Figure 1). Furthermore, the DNOs are the main point of interaction between the power grid and the end-users; therefore, implementing new concepts such as demand response, smart metering, and consumer empowerment involves changes in planning and operation at the distribution level.

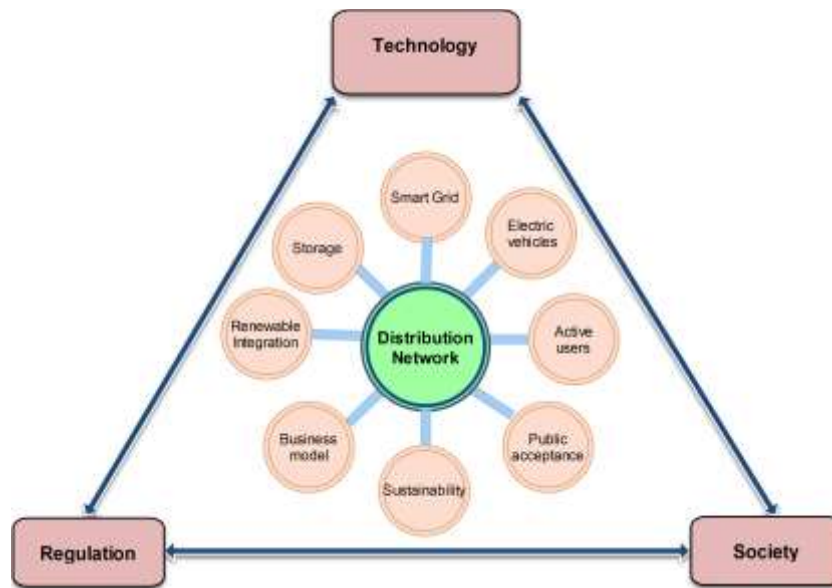


Figure 1. Electricity distribution networks in a dynamic environment
Source: Authors

These developments will lead to fundamental changes to the relationship between utility companies and their customers, which will result in the emergence of new business models. Future distribution network utilities will adapt their conventional business models based on the provision of unidirectional wire connection to innovative and interactive service-based business models.

The outline of this chapter is as follows. The following section discusses penetration of new technologies and their implication for network companies. Section 3 explains the role of consumers and society and the change in the nature of demand. Regulatory challenges and possible solutions are discussed in Section 4. Section 5 investigates the problem of the current stylized business model of the DNOs and explores some possibilities in this respect. Finally, conclusions are drawn in Section 6.

2. New technologies: Game changers

2.1 Distributed energy resources

Distributed energy resources are facilities that can generate electricity (and heat) using several small- and medium-scale technologies. These include different types of distributed generations (DGs) such as small turbines, fuel cells, combined heat and power (CHP), and photovoltaic systems (IEA, 2002). These facilities either connect to the distribution network or serve customers directly on-site. This differs from the traditional system, which produces electricity in a few large facilities that is then transported over long distances through transmission and distribution networks to reach consumers.

Distributed sources have several possible benefits. A greater number of local generation facilities can potentially reduce congestion in the network and defer upgrades to transmission and distribution systems. Additionally, quality of supply can increase as energy is generated closer to demand, and system losses may also decrease (IEA, 2002). Distributed generation currently accounts for a small proportion of total capacity, but this share is set to increase as these technologies improve. Furthermore, growing concerns over climate change, constraints in upgrading the transmission grid, and supply security are increasing the number of generators connected to distribution networks (IEA, 2002).

However, large volumes of distributed generation can affect the quality of supply, voltage levels, and phase imbalance (Putrus *et al.*, 2009), whilst large increases in renewable sources can create new bottlenecks in distribution networks. In passive networks, the distributed generation capacity that can be connected is limited as network stability is essential for a safe and secure supply, and large volumes of distributed generation may cause system volatility (Lopes *et al.*, 2007). Therefore, the networks require substantial investment for upgrades and expansion to accommodate the diverse distributed energy sources.

Alongside the increased focus on distributed generation is the prospect of development of storage technologies. Depending on the duration of storage, benefits include voltage and frequency control (short storage), peak load topping, renewable power smoothing (medium storage), smoothing of weather effects, and annual smoothing of loads (long storage). Thus, energy storage can increase the penetration of distributed generation by ensuring a smoother supply and offering greater demand predictability (Barton and Infield, 2004). This holds out the potential for electricity customers to become less dependent on the networks, so that DNOs will need to find alternative methods of securing their revenue base.

2.2 *The smart information and communication technology era: Smart grids and meters*

Conventional distribution networks are passive and operate based on predefined values, and are thus unable to respond to short-term customer behavior. They are also unable to accommodate the wide range of renewable and distributed energy sources. Therefore, large increases in distributed generation and EV necessitate the development of active networks with the ability to respond to changes in demand and supply. A smart grid uses information and communication technology (ICT) to collect and respond to information about customer and supplier behavior. With two-way communication technologies and smart meters, the networks can better respond to changes in demand, aggregate consumption, and grid condition, enabling informed participation by their customers (Byun *et al.*, 2011).

However, the implementation of smart technology does not automatically lead to smart network operation. The transition must be comprehensive, and requires retraining of staff as well as development and implementation of new protocols that are compatible with the new operating environment (Arends and Hendriks, 2014). Moreover, the costs associated with active smart networks are substantial, and their benefits need to justify and outweigh their costs. In the conventional business model, DNOs do not normally have an incentive to implement a responsive grid as they would only be able to offer limited benefits (Lopes *et al.*, 2007).

2.3 *Electric vehicles*

Whilst CO₂ emissions from some sectors of the economy are decreasing, emissions from transportation are increasing (DECC, 2014). The UK government has implemented a number of measures to incentivize the public to switch from traditional vehicles, which run on petrol or diesel, to EV. These measures include grants, road tax waivers, and exemption from London congestion charges (TRL, 2013). With costs being a major motive behind purchases (TRL, 2013), financial incentives and technological progress can increase the uptake of EV in the UK (Putrus *et al.*, 2009). However, to date, interest in the UK has been slow, and only 5 percent of consumers were considering buying an electric car or van in the near future as of 2014 (Department for Transport, 2014). On the other hand, strong incentives in countries such as Norway have resulted in a greater demand for electric cars.

Electric vehicles have yet to make a substantial impact on the distribution network; however, since the vehicles use batteries with large storage capacity, allowing them to travel longer distances, an upsurge in uptake may place strain on the network. One potential problem relates to a mismatch of supply and demand due to uncertainties regarding when and how owners charge their vehicles. The distribution grids can only safely carry up to a certain load, and if owners charge their vehicles at peak demand hours, a congested network may overload. Therefore, substantial local infrastructural reinforcements are required to accommodate the integration of EV (Lopes *et al.*, 2011).

As the number of vehicles increases, the DNOs will need to upgrade the network to supply the charging points and other required infrastructure (Pieltain Fernández *et al.*, 2011). However, provided that the necessary infrastructure is in place, the vehicles may be able to deliver electricity back to the grid. This opens the possibility for electric cars to provide peak-demand relief, which would reduce the need for grid capacity enhancement. Additionally, the potential mismatch between demand and supply can be eliminated through improved communication and provision of price incentives to consumers to encourage off-peak charging (Putrus *et al.*, 2009).

The aforementioned changes in the operating environment of distribution networks will necessitate a shift in the operating philosophy of these companies from being network operators (DNOs) to distribution system operators (DSOs). Figure 2 illustrates this likely transition, and depicts and relates the above-discussed aspects of technological change in the operating environment of the DNOs, including distributed generation, storage facilities, ICTs, and EV.

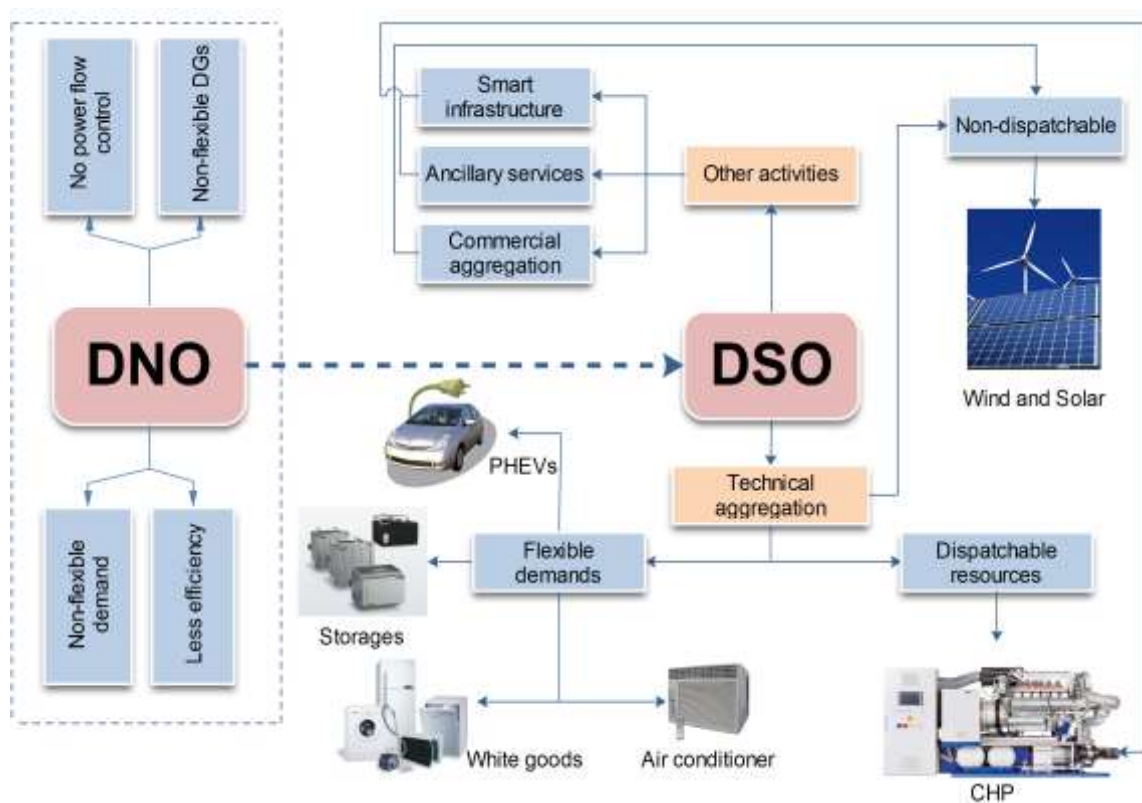


Figure 2. A shift from DNO to DSO
Source: Poudineh and Jamasb (2014)

3. The consumer and society: The changing nature of demand

Governments across Europe have set ambitious green energy targets to curb emissions. The policies, including increased generation of renewable energy and EV expansion, largely depend on public and local support for their success. The role of the individual and the community in energy policy issues is thus on the rise (Akcura *et al.*, 2011). This trend is also noticeable in the transportation of electricity. The technical challenges of DNOs to ensure a sustainable energy future include extensive expansion and modernization of the networks to allow for smaller but more numerous generation facilities, uptake of EV, and active grid management. However, whilst the technical and economic aspects receive more attention from the sector and academics alike, they are only part of the challenge. As the nature of electricity demand and supply is changing, so is the role of the society and consumer engagement in the sector.

Societal and consumer acceptance of green energy innovations plays an important part in addressing and curbing climate change. Whilst it is generally thought that public attitudes towards renewable energy are positive, local opposition to large facilities remains significant. The importance of public acceptance has been discussed with regards to large infrastructural projects, such as transmission lines (Ciupuliga and Cuppen, 2013), renewable-energy-generation technologies (Devine-Wright, 2011), and hazardous facilities (Johnson and Scicchitano, 2012). However, where large infrastructure, put simply, only needs “passive” consent (see Ciupuliga and Cuppen, 2013; Tobiasson and Jamasb, 2014), distributed generation, EV, and smart networks depend on “active” acceptance from consumers. This includes the willingness to invest, install, and change behavior to adapt these technologies (Sauter and Watson, 2007). The slow progress from simple acceptance to participation and changing behavior shows how priorities expressed by citizens sometimes fail to translate into actions by customers (Cotton and Devine-Wright, 2012).

The shift to a decentralized generation mix creates a flow of electricity that is less predictable and less flexible to operate. Shifts in both demand and supply will have an effect on the operation of DNOs. Through increased uptake of demand–response, smart grids, and distributed generation, customers are more involved and can actively contribute to increased energy efficiency, energy saving, and peak load shifts. Not only are customers able to affect the demand side through altering electricity consumption patterns, but also the supply side, where consumers can take on the role of producer through distributed generation (Mah *et al.*, 2012).

Moreover, customer action is the main driver behind reaching the policy goals to curb climate change, and customer engagement should therefore be a priority (Honebein *et al.*, 2011). Smart grids and distributed generation require communication between utility companies and their customers. The relationship is likely to change from a one-

way information flow to a two-way interactive discussion. However, not only will the DNOs be required to engage actively with customers once new technologies are implemented, through dialogue at an early stage, but DNOs can also learn about their customers' priorities and concerns, and adapt these technologies accordingly. Early communication and customer participation is important for building trust and confidence among consumers, which in turn is important for achieving customer acceptance of new technologies (Gangale *et al.*, 2013).

Ultimately, increasing communication and participation with customers will bring to light the heterogeneity of customer behavior, as the same technology may be perceived differently among different groups in the same or different communities (Batel and Devine-Wright, 2014). The role of the consumer in the sector is shifting. As distribution networks change from passive to active utilities, the public is also changing from being a passive to active stakeholder. On the other hand, DNOs face the challenge of adapting to a new nature of demand. However, rather than adopting a "wait and see" approach, the DNOs can also choose to act early and smooth the transition from passive transporters of electricity to active participants in between both demand and supply. Therefore, policy makers and regulators have the challenging task of providing incentives that increase public acceptance and participation in implementing green-energy innovations.

4. Regulation: Incentives work

Maintaining a well-functioning liberalized sector requires supervision and regulation of the wholesale and retail markets as well as the networks services. At grid level, this becomes more important as there is no competition and the networks are subject to incentive-based regulation. The incentive regulation regimes aim to induce the market outcomes in this segment of the sector. The expectation is that incentive regulation better realizes the objectives of regulators. However, the post-liberalization experience has shown that incentive regimes give rise to new challenges, including those related to investments and innovation. Additionally, promotion of low-carbon technologies and objectives has resulted in new challenges that require regulatory innovation and solutions. In what follows, we review some of the most important regulatory challenges that will likely affect future development of electricity distribution networks.

4.1 Investment and innovation

The post-liberalization policies of achieving a low-carbon economy have changed the dynamics of the electricity sector. This is reflected in the need for smart technologies, distributed-energy resources, EV, network security, and integration of electricity markets. Achieving these objectives calls for substantial innovation and investments,

and ensuring sufficient and efficient investments in the networks is among the most challenging tasks facing regulators.

The current regulatory models of investment treatment are either *ex ante*, *ex post*, or a combination of the two. Under the *ex-ante* model, network companies need to submit business plans that contain details of their investment needs over the subsequent regulatory period. The regulator uses auditing, cost–benefit analysis, and consultants to verify the prudence of investments plans. At the end of the regulatory period, if there is a deviation from the agreed level of capital expenditures in the business plan, the regulator might partially or totally disallow the excess investment.

The *ex-ante* approach has been criticized on the grounds that it provides incentive for strategic behavior. For example, network companies will have incentive to inflate their capital costs by reporting high volumes of work or by capitalizing their operational expenditures. Averch and Johnson (1967) demonstrated that under this model firms will, for a given level of output, employ more capital compared to non-regulated companies. The incentive for overcapitalization will be higher if there is no incentive attached to downward deviation from the agreed level of investment in the business plan. The planned RIIO (Revenue=Incentives+Innovation+Output) which is a framework for regulating the network companies in the UK aims to promote innovation and efficiency by allowing the firms to retain some of their capital cost saving if they deliver the same output with less investment.

In *ex-post* regulation, the regulator adds the controllable costs incurred to the company, including the operating and capital expenditures, in order to construct a single variable reflecting the total cost. The total cost is then benchmarked against the similar companies in the sector to obtain the cost efficiency. The firms' revenue is set based on their deviation from the optimum frontier. The threat of financial loss from the benchmarking process can lead to an efficient level of operating and capital expenditure. Poudineh and Jamasb (2016) showed that this model is vulnerable to harmonized behaviors, such as over- and under-investment by utilities. Harmonized behavior changes the costs for companies uniformly, and within-group comparisons cannot detect the incidence of overcapitalization. Additionally, the minimum productivity level to pass a benchmarking exercise (that is, no-impact efficiency) is also vulnerable to harmonized behavior.

Regulatory treatment of investment presents a trade-off between intervention in firms' operation and distribution of risk between the firms and their consumers. The *ex-ante* model is more interventionist, but the firm bears little risk compared to the consumers. This is because consumers are more likely to be exposed to the actual costs of the firm rather than the efficient costs. The *ex-post* model, on the other hand, is less interventionist, but firms bear more risk compared to consumers. The choice between

the two approaches depends on the regulator's view of intervention and risk. Nevertheless, both models suffer from a lack of incentive for dynamic efficiency.

As noted by Müller *et al.* (2010), under incentive regimes (both *ex ante* and *ex post*), efficiency gain has mainly been achieved in operating costs, but regulatory models do not incentivize dynamic, efficient behavior among firms. In the case of *ex-post* regulatory treatment of investment, Poudineh *et al.* (2014) showed that persistent inefficiency due to the presence of quasi-fixed inputs, such as capital costs, can affect companies' short-run productivity and regulated revenue. This can create disincentives for long-term investment and innovation. In the case of *ex-ante* regulation, although capital costs are excluded from benchmarking, the model does not provide explicit incentives for dynamically efficient behavior.

4.2 Incentives and alignment of benefits

In order to unlock the system-wide benefits of dynamic networks, the incentives that guide the behavior of players need to be realigned. Additionally, policies need to serve the diverse interests of distributed resource developers and consumers. The public, as well as community engagement with the sector as consumers and as citizens, can affect the development of the network and energy infrastructures. Some projects have stood still because local communities perceive them as failing to meet their objectives. The need for involvement of customers in the planning of new projects or through demand-side participation requires a new consumer–distribution utility relationship.

Consumers with micro-generation, EV, and storage capability are no longer passive users, but can benefit or harm the system. The load from EV varies with respect to time and location. In the absence of incentives, the EV owner indifferently charges and discharges at any time and place. However, the power system would benefit from charging during off-peak periods and in uncongested areas, and discharging at peak times and in congested zones. Thus, there is a need for incentive signals that coordinate the actions of players to the advantage of power system reliability and efficiency. However, current regulatory models do not provide such incentives and thus are contrary to the paradigm of a sustainable power sector.

The current incentives for the integration of distributed resources are not directly relevant in terms of impact on network infrastructure and generation supply. For example, siting a distributed generation (DG) close to demand centers or areas served by frequently congested lines will be beneficial for a DNO as it can reduce network energy losses and have an impact on demand-driven investments. DG can have various effects on the grid, depending on factors such as location, technological specification, and timing of investments (Vogel, 2009). The lack of a mechanism that aligns these benefits between the DG developer and the DNO might reverse the expected advantages of DG integration.

An example of this is network energy losses. Networks are incentivized to reduce such losses and are rewarded or penalized for outperforming or underperforming on the loss targets. Although DG can reduce these losses, it is generally bound by time and location and, under the condition that capacity exceeds the demand, it can increase overall energy losses because the relationship between capacity and loss is U-shaped (Harrison *et al.*, 2007). Therefore, DNOs might be exposed to DG-induced losses, with consequences for their revenue. On the other hand, generators are not incentivized for their positive or negative effect on network energy losses. Hence, there is a conflict between the interest of developers wishing to increase DG penetration and the DNO that wants to avoid DG-induced losses.

One solution is to use efficient and effective connection and “use of system” (UoS) charges—a mechanism that not only includes the real cost of connection but also rewards the developer when DG installation is in line with the optimal operation of the network (Jamashb *et al.*, 2005). The distribution UoS charges can play a role, as DGs’ connection charges could be based on their capacity and the sole-use network asset used. On the other hand, rewards can be offered based on generator-exported power at system peak, proximity to frequently congested zones, and network assets utilized (Poudineh and Jamashb, 2014). This ensures that rewards will reflect the benefits from integration of the resource. Taking into account the cost drivers when devising the charges and rewards will help to guarantee that they are aligned with the costs imposed by DGs on the network.

4.3 Managing uncertainties

There are several sources of uncertainty in the operating environment of distribution network companies, which call for uncertainty to be incorporated into regulatory models. These include future tightening of environmental policies, change in price of fossil fuels and its effect on the rate of growth of renewable resources, cost and performance of networks, carbon prices, uncertain demand and economic growth, availability of capital, and finally, change in the behavior and expectations of consumers.

DNOs face significant uncertainty from unexpected changes in the aforementioned factors. These factors can impact the existing infrastructures in terms of planning and operation, as well as development of new assets. The network infrastructures are long-lived assets and irreversible investments. Hence, insufficient consideration of uncertainty in the regulatory and decision-making process can lead to negative consequences for the firm and consumers. The regulatory framework should also recognize the increasing importance of local communities as part of the low-carbon solution, and provide incentives for these communities to become part of the solution for future networks.

Thus, given the importance of uncertainty, there is a need for regulatory models that reduce the exposure of firms and society to the adverse effects of changes in the operating environments of network companies. Furthermore, uncertainty is not welcomed by investors, who are interested in a stable return on their investments. Uncertainty means risk, which is likely to erode creditworthiness of the utilities and manifest in the form of higher capital costs and thus higher bills for consumers. This will lead to reduction of capital availability, which affects DNOs' future investment plans. These cycles have previously been experienced in other network industries, including telecommunications and airlines.

5. The utility business model: What future?

There is limited consensus on the definition of a business model (Desyllas and Sako, 2013). However, there is more agreement that business models are at the core of strategies for surviving in a dynamic environment. In recent years, electricity distribution networks have experienced rapid changes in their environment as a result of energy and sustainability policies. These changes not only influence technical operation of the grid, but also its economics and revenue generation. Evidence suggests that network companies cannot continue with traditional business models in the new environment (Poudineh and Jamasb, 2014). This section reviews the effects of large-scale integration of distributed energy resources on the business model of distribution companies, and explores possibilities for alternative models.

5.1 Disruptive technologies and DNO revenues

A variety of new technologies and factors exist, including photovoltaic cells, micro turbines, micro CHP, fuel cells, storage facilities, demand response, and energy efficiency, which can all have disruptive effects on the revenue of distribution network companies. As distributed technologies are on a descending cost trajectory, the traditional generation–transmission–distribution paradigm comes under increasing pressure to be changed. The threat to the traditional centralized supply will be exacerbated by behavioral change, which may lead to reduced load. The proximity of distributed resources to demand sites reduces the volume of energy transported in the grid and consequently erodes the revenue base of network companies over time.

The current incentives to promote renewable distributed generation are characterized by a tendency to work at cross-purpose with the original objective. It is conceivable that some consumers will choose to leave the grid entirely if there are other cost-effective possibilities available. For example, this can occur when storage facilities such as those of plug-in vehicles are combined with suitable distributed generation. In a more optimistic scenario, consumers will use the grid only as a backup and aim to be self-

sufficient otherwise. In this case, the networks will not be able to recover their costs from consumers who install self-generation facilities, especially those installed behind the meter because they do not pay for grid connection.

Furthermore, while the total network cost will barely change with the exit of an existing customer, the remaining consumers will incur the cost burden of the network. These are often the same consumers who cannot afford self-generation in the first place. The increase of electricity rates will create positive feedback, which results in more independence from networks. Moreover, due to the structure of retail tariffs in some countries, penetration of distributed resources has not led to a reduction in peak demand, but rather a reduction in average demand (Nelson *et al.*, 2014). This implies a rise in the network costs imposed by other consumers who do not pay for network charges.

Furthermore, the paradoxical nature of consumers-side renewable with the business model of utilities deters integration of small-scale, low-carbon technologies from gaining sufficient momentum. Although in recent years some incumbent utility companies have been providing various services for their consumers, such as consulting services on energy efficiency and financial support to install rooftop PV (photovoltaic), managers of these utilities often acknowledge that such activities are inherently counterproductive given their current business model (Richter, 2013). Thus, as residential renewable generation currently does not benefit utility companies, in practice the promotion of these resources is not supported by these companies, and where there is evidence to the contrary, it is mainly to show political goodwill or to manage the consumer–utility-firm relationship.

The challenge of disruptive technologies gives rise to the idea that the power industry needs to shift from the traditional business model of selling energy in terms of kWh (or MWh) to something that is not in conflict with other policy objectives, such as sustainability. As demand for energy is a derived one—that is, consumers do not gain utility from energy itself but rather from the services they obtain, such as heat, light, computer hours, entertainment, etc.—a solution for utility companies to adapt to their dynamic environment is to consider selling the unit of “energy service”. In this view, the consumer bill can resemble a list of energy-based services, such as heating, cooling, interior and exterior lighting, etc. These ideas are not completely new. Indeed, during the last four decades some pioneering energy-policy thinkers have suggested that utility companies should sell energy services. Such a model will push utility companies towards the business of end-use hardware appliances. Similar models have been developed in the telecommunications industry, where consumers actually receive kilobits per second (Kbps) while the service providers charge their consumers for minutes of talk, number of text messages, amount of data downloaded, etc.

The emergence of smart technologies brings such ideas closer to reality. Two-way communication and advanced sensors that are becoming increasingly commonplace within the current power infrastructure reduce measurement problems that were considered an impediment to implementation of this kind of model in the past.

5.2 Innovation in business models

There have been important discussions around the future business models for distribution network companies and potential regulatory models that can support these companies through a rapidly changing landscape. Common among many of the discussions is that the network companies need to go beyond only connection and UoS charges. The utility companies will need to work closely with consumers, resource developers, and other stakeholders to create an integrated-value partnership. Decoupling the revenue of network companies from aggregate energy usage is not only important for the companies, but also for achieving energy-efficiency initiatives that can be opposed by distribution networks (Brennan, 2014).

An issue is that even if utility companies have the resources to introduce new ideas and products, they often fail to successfully commercialize them. Experiences from the past in other industries show that this has sometimes been the case. For example, at the end of the 1990s, IBM was among the first companies to develop new technologies such as commercial routers and speech recognition, but these entered the market later, produced by other companies and not IBM (Richter, 2013). Another issue is that network companies are regulated businesses and innovation in such an environment is only derived from incentives and institutional frameworks.

Despite these challenges, there are potential areas that can be utilized in an extended business model of distribution network companies. Although some research suggests that the critical skill for traditional players is not to create new business models but instead to identify and implement the already existing ideas into a mass-market scale (Nillesen *et al.*, 2014). These arguments are based on experiences from other industries, where the majority of new business models have been created by newcomers but implemented on a large scale by incumbents.

An important dimension of any future business model would relate to digital-communication capabilities. The ICT revolution in the last century has embraced all sectors, including electricity distribution. The change from capital-intensive to information-intensive business has already been initiated in this segment of the power sector. This provides valuable system data for distribution utilities, which can be shared with developers of distributed energy resources and retail suppliers for efficient planning and operation in return for a payoff.

Figure 3 presents an extended business model for distribution network companies. Transmission system operators (TSOs) often procure balancing services. Penetration of distributed energy resources provides an opportunity for DSOs to contribute to national balancing services and be compensated for it by the TSO. As seen in Figure 3, the costs of a DSO consist of grid reinforcement, use of (transmission) system charges, ancillary services procured from the transmission operator, operation and maintenance, and finally, energy losses.

On the cost side, a DSO can optimize its capital expenditures through adopting innovative approaches to the problem of grid reinforcement. The traditional asset-based network service is capital intensive and costly. DSOs can optimize on network infrastructures by combining asset-based service and an alternative approach based on procurement of distributed energy resources that can provide network capacity. These resources can deliver energy at the time of network congestion, and thereby reduce the need for costly redundant transformers.

Another important feature of this approach is that it provides more flexibility to DSOs compared with traditional network reinforcement. Integrating distributed resources to offer services, such as voltage control and congestion management, could provide various benefits for utilities, grid users, and wider society. However, for this to happen, a suitable business model is required. Poudineh and Jamasb (2014) introduced a contract for deferral scheme (CDS) that integrates distributed generation, storage, demand response, and energy efficiency as alternatives to grid capacity enhancement. This method can lower capital costs for network companies and also boost deployment of low-carbon technologies.

On the other hand, as shown in Figure 3 the revenue of a DSO comprises connection and UoS charges, data supply to resource developers and retailers (this is likely to be a possibility as the future smart grid becomes a reality), contribution to the national balancing service, and offering premium reliability. A DSO with smart grid technology can communicate with generation facilities and consumption equipment on the consumers' site through a secure connection. This means that the DSO can increase generation or reduce demand at times of stress to the national grid, hence stabilizing electricity supplies. Furthermore, in many industries the production process is sensitive to electricity inputs, and DSOs can be reimbursed by these industries for providing a highly reliable connection (Poudineh and Jamasb, 2014).

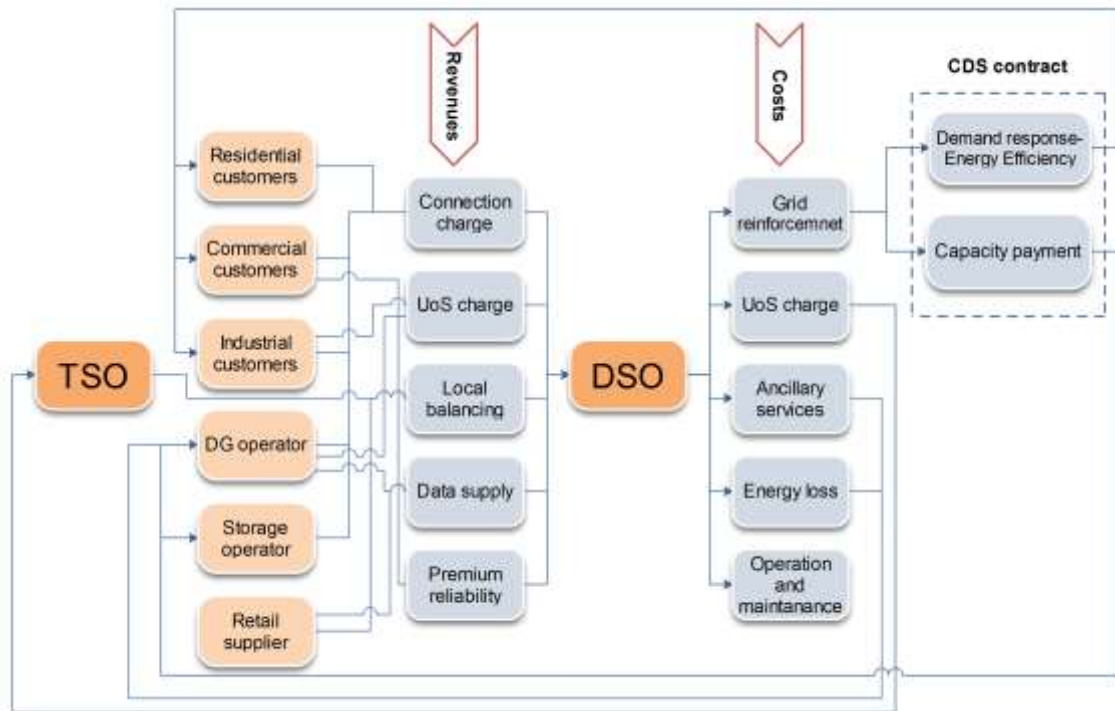


Figure 3. An extended business model for distribution networks

Source: Poudineh and Jamasb (2014)

6. Conclusions

Electricity distribution networks are an important component of the power system that delivers energy to end-users and plays a key role in the integration of distributed energy resources, security of supply, and demand-side participations. The post-liberalization era has necessitated technological, regulatory, and business-model evolution in electricity-distribution companies.

Adoption of distributed energy resources and EV require innovation and large-scale investment as the grid requires reinforcement and reconfiguration to accommodate them. The ICT revolution has extended digital communication capabilities to the grid level, with ample opportunities for new services. The DNOs can integrate virtual power plants by aggregating many small-scale renewables, thereby providing greater efficiency and flexibility. This is important, given that the installed capacity of variable generation from wind and solar power is increasing every year.

At the same time, the regulatory framework of network companies needs to evolve in order to better align with the objective of an efficient, low-carbon power sector. The current regulatory models for investment treatment do not take into account the dynamic nature of investment and innovation. Strong emphasis on short-run cost efficiency can result in reduction of research and development and capital expenditure as network

companies cannot afford persistent inefficiency caused by long-term investment plans. Therefore, there is a need for innovative regulatory models that incentivize innovation and the right investments without compromising other objectives, such cost efficiency.

Moreover, a shift from an asset-based, capital-intensive business model of distribution utility is crucial in order to adapt to an environment with high levels of penetration of distributed energy resources. Along with the traditional connection and use of system charges, future business models of network companies can tap into smart ICT technology to create new and value-added services.

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¹ This chapter draws substantially from different parts of Poudineh (2014).

² There are two main types of substations associated with the distribution system: the primary substations, which act as load centers located near populated areas, and the customer substations, which are situated close to consumer sites and convert the voltage to a suitable level for consumption.